Part III.

Validation Monitoring of Watershed Restoration in California

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Draft Final Report to the Department of Fish and Game
Contract Manager: Barry Collins
Interagency Agreement No. P0010564

February 2003

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Introduction

Basic Life History of Salmon and Steelhead in California

Coho Salmon. Juvenile coho salmon, (at least the large majority of those life history types that still exist), spend their entire freshwater residence in or near their small natal streams. If trapping sites are located on large enough streams such that juvenile rearing occurs primarily above the trap sites, adult and juvenile migrant trapping will provide information on the freshwater and marine survival of coho salmon. Marine survival, as we use it here, encompasses the survival of fish from the time the smolts migrate out of the study stream until the adults return to the stream. Thus, this survival includes migration through mainstems and estuaries as both smolts and adults.

Chinook Salmon. Most fall chinook juveniles migrate out of their natal stream by the early summer, and continue rearing in the mainstem rivers and estuaries before migrating to the ocean in late summer and fall. Because of this life history pattern, the trapping program will not be able to estimate marine survival rates for chinook salmon. Trapping will provide estimates of the number presmolt chinook leaving the streams each year. In addition, information on size of migrants and the timing of the migration will be collected.

Steelhead. Steelhead juveniles may move and rear considerable distances from their natal streams before they make their seaward migration. Therefore, unless trapping operations are located near the ocean, no estimate of the total number of ocean migrating juvenile steelhead produced from a known number of adult spawners can be obtained. Consequently, in most cases trapping will not provide information on the marine and freshwater survival of steelhead. Those sites located in the lower portions of river basins will provide information on smolt abundance each year. The sampling will also provide information on the migration timing, and the size and age of the migrants.

Coastal Cutthroat Trout. The freshwater life history of coastal cutthroat trout, which is similar to that of steelhead, presents similar obstacles to using trapping information to estimate their freshwater and marine survival. In addition, the small size of returning searun cutthroat trout adults makes them difficult to trap. Most returning searun cutthroat are small enough to swim through the upper picket fence in the adult trap. In most cases the spacing of the bars in the picket fence cannot be reduced to insure the capture of all searun cutthroat because it would result in the adult trap clogging with debris during high stream flows. Therefore, in most cases, trapping will only enable monitoring of trends in the number of downstream juvenile migrant cutthroat trout. Experiments are currently being conducted with an infrared fish counter that may enable us to count returning adult searun cutthroat trout without actually capturing them in a trap.

VALIDATION MONITORING PROTOCOLS

1. JUVENILE SALMON AND STEELHEAD ABUNDANCE AND POPULATION SIZE

Abundance and population size are terms used, in fisheries biology, to express two similar but different measures. Abundance refers to the number of fish sampled in an area. Abundance is often expressed as the catch given some standardized unit of effort (CPUE), for example the catch per hour of electrofishing. It is sometimes expressed as the number per unit area, in which case it may be referred to as density.

Population size refers to the absolute number of fish in a defined area consisting of multiple habitat units. The area is most often an entire stream or reach of stream having similar habitat conditions. Estimates of population size could be obtained from sampling the entire area of interest, but is usually obtained by sampling a statistically selected sub-sample from those habitats available, then extrapolating to the total area of habitat.

I. Rational

The number of juvenile salmon or steelhead present in a stream or stream reach often requires less effort than estimating abundance of other life history stages, such as adults, smolts or eggs. Measurements of the number of juvenile salmon or steelhead present in a stream also provides several types of information useful to monitoring. First, when measured over multiple years these measures provide information on the response of salmon and steelhead to environmental and other conditions. Second, when combined with measures of the number of adults spawning, they provide information of survival from during the egg to juvenile period. Third, when combined with data on the number of smolts migrating from a stream, they provide information on survival during the entire juvenile period.

Methods described here are intended to provide information on juvenile salmon or steelhead abundance and population estimates. Abundance estimates require less rigorous sampling and are usually better suited to monitoring population trends or the response of a watershed to management actions. For example, measuring change in the abundance of juvenile salmonids over time. However, more rigorous sampling for population estimates is required when comparisons of survival at distinct life stages is desirable.

II. Limitations

Methods described here are intended for small – medium size streams in which most pools (>75%) are <1.1m in deep ant the stream has a wetted perimeter of ≤ 10 m. Water in streams must also allow divers to see fish clearly at 3-5 m if visual counts of juvenile salmonids are to be considered reliable.

These conditions are necessary for two divers to effectively sample a stream. Streams that are too large to be sampled with snorkeling should be sampled with electrofishing equipment. Similarly, streams too small to dive or in which the visibility is limited should be sampled with electrofishing equipment.

Sampling during August – October will insure that meeting these requirements is most probable. During this period, water clarity in California streams is greatest and juvenile coho salmon and steelhead are large enough to be visually located and distinguished.

III. Sampling Methods

A. Estimating Abundance

Estimating the abundance of fish in an area requires information on the habitat and fish. This information is gathered in two steps, first, the habitat available is classified and second, the fish using those habitats are counted.

1. Measuring habitats

Two people are needed to classify and measure habitat units. Habitat measurements should be completed soon enough before fish sampling that habitat depths and areas do not change during the interval. In measuring habitats, one person carries a hip-chain to measure linear distance from the starting point and a stadia rod to measure width of the habitat units and their depth, if desired. A second person records data. All habitat units within the stream or stream reach in which abundance estimates are to be made must be classified and measured.

Individual habitat units are classified as either runs, riffles, pools, deep pools or other habitats. Each habitat unit must be longer than its average width. It should be separated from neighboring habitat units by a distinct hydraulic break so that movement of fish between units during the dive survey is limited. Habitat units that appear to be comprised of two habitat types should be classified to reflect the majority of the unit. General definitions of habitat types for fish sampling adopted from Flosie et al. (2000) are:

1. Pool (P) - a scoured habitat unit with slow currents, little surface turbulence, and maximum depth < 1.1 m.
2. Run (N) – quickly flowing water having little surface agitation and few occurrences of substrate breaking the surface. In defining habitat for fish sampling, we recommend combining glide and run habitats as defined by Flosie et al. (2000). Run habitats have a minimum of 60% of their area in water > 40 cm deep.
3. Riffle (R) – habitats with fast-flowing water and substrate breaking the surface, causing surface turbulence. Riffle habitats are too shallow to dive.
4. Deep Pool (DP) – a scoured habitat unit with slow currents, little surface turbulence and a maximum depth > 1.1 m.
5. Other (O) – other habitats are those that present features that make either snorkel observations or electro-fishing difficult. For example; side channel habitats may be small and shallow relative to the main channel, or habitats having complex structures that present obstacles to visual recording or netting of fish.

Habitat unit length, width, depth and surface area are recorded on the data sheet (Appendix table 1) in numerical sequential order (NSO) from the downstream starting point. Each NSO number can then be associated with a specific habitat unit.

Time and effort of measuring habitats can be reduced by visually estimating surface area of the habitat. If visual estimation is used, accurate measurements should be recorded on subset of the total of each habitat type. This can be accomplished by systematic random sampling (see Box 5.1).

Box 1.1. Instructions for systematic random sample selection.

Steps in systematic sampling if 20% of the total habitat units are selected for accurate measurement.

1. For each habitat type, first draw a random starting number between 1 and 5. If, for example, the starting random number for pool habitats was 3, then accurate measurements should be recorded on NSO 3, 8, 13, 18, 23, etc. until the survey is completed. A separate random starting number must be drawn for each habitat type.
2. Visually estimate and record the area of the habitat unit.
3. Physically measure and record the area and habitat characteristics of that unit.
4. Physically measure and record habitat characteristics on units at the same interval between units.
5. Calculate a calibration ratio (Q) using at least 10 habitat units:

   $Q = \Sigma m_j / \Sigma x_j$, where m_j = the accurate measurement of habitat area and x_j = the visual estimate of habitat area.
6. The total area of each habitat type (M) may then be estimated from:

   $M = T_x * Q$, where $T_x = \Sigma x_j$ = sum of 1 to N visual estimates of area for a habitat type and N = the total number of units of a particular habitat type.
7. The variance (V, a measure of uncertainty) of the estimated total habitat type can then be calculated from:

   $V(M) \simeq [N^2 * (N-n) / N*n] * [\Sigma(m_j - Qx_j)^2 / n - 1]$, where n = sample size or number of accurately measured habitats.

Accurate measurement of habitat units should follow standardized procedures. We recommend measuring width in 2 m intervals on simple habitats. Measurement interval may require adjustment on irregularly shaped habitat units. Use width measurements to calculate average width, and multiply average width by habitat length to obtain surface area.

2. Conducting the Fish Census

The primary sampling method recommended for counting fish is visual observation using snorkel gear. This method is less costly and intrusive than other methods. However, visual observation techniques are not possible in all types of habitats, nor are they applicable in some streams. Electro-fishing is recommended in situations where visual observation is either not possible or would provide inaccurate results. Methods for electro-fishing are described later in this section.

Visual observation may be used to sample run, pool, and deep pool habitats. A systematic random sample of each habitat type should be drawn from the total of habitat units measured (Hankin and Reeves 1988). Selection of fish sampling units may be carried out using the methods described in box 5.1. The proportion of units selected for sampling can differ among habitat types. For example, sampling could include 30% of pool and run habitats, but only 10% of riffle habitats. If the proportion of habitat units to be sampled is determined before habitats are classified, the upper and lower boundaries of habitat units selected for later fish sampling should be marked with flagging during habitat surveys. Having habitat surveyors delineate those habitats to be sampled for fish minimizes uncertainty in later locating specific habitat units and delineating their boundaries.

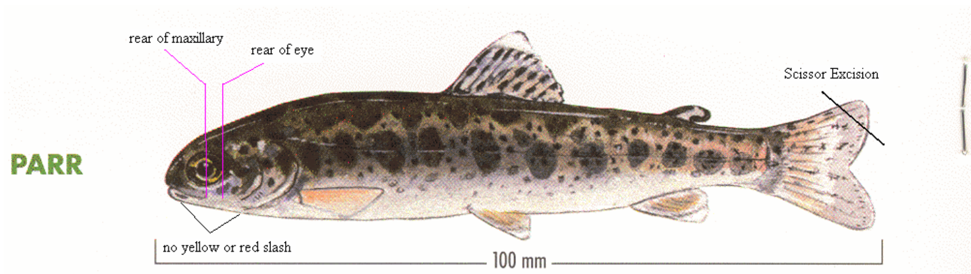
Two pool or run habitat units outside the area to be sampled should be identified for practice. Snorkel divers should survey these habitats before starting the fish survey. These practice habitats allow the divers' to familiarize themselves with the species and size classes of salmonids they will likely encounter in subsequent habitats. Ages and size classes of salmonids can very among streams during any season because of differences in time of emergence and growth.

Identification of all species can be problematic within the range of coastal cutthroat trout. Juvenile steelhead and cutthroat trout cannot be consistently distinguished until the reach a length of around 80 mm fork length (Figure 5.1). Thus, from the Eel River northward, small trout should be counted as age 0+ trout species. Steelhead and cutthroat trout > 80 mm FL can usually be assigned to age 1+ of their species. However, these species should be recorded as age 1+ trout if divers are not confident in their ability to separate these species.

The fish census is conducted primarily by visual observation using snorkeling, with limited electro-fishing. Visual observations of pre-selected pool, deep pool and run habitats are conducted, progressing from downstream to upstream. Divers should enter the downstream end the habitat unit to be surveyed. They should move upstream, parallel to one another, through the habitat unit using deliberate movements so as to minimize disturbance to fish. Fish are counted as divers move upstream and recorded using either a hand counter or underwater record slate. Using a recording device is especially important where fish are abundant and where multiple species occur. After completing the census for a specific habitat unit, data are recorded in small "Write-in-the-Rain" or plastic paper notebooks than can be carried in a dive pouch.

Visual observation methods are not possible in riffle habitats and may not be effective for entire reaches of some shallow streams. Furthermore, cobble and other obstructions in riffle and other shallow habitats also make seine netting inefficient. These habitats must be sampled using electro-fishing techniques.

A



B

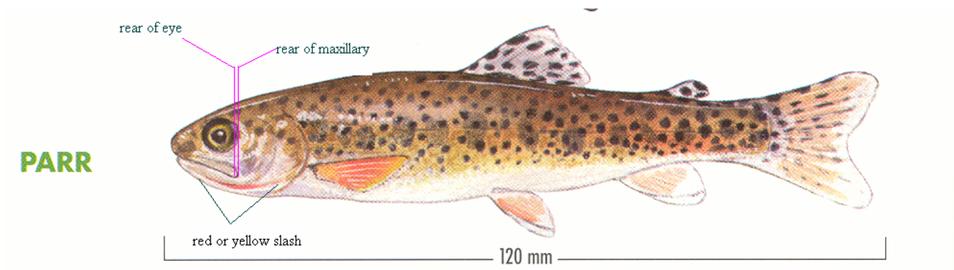


Figure 1.1. A) Steelhead parr illustrating the location of the eye relative to the length of the maxillary and lack of a red or yellow jaw slash and B) cutthroat trout parr illustrating the location of the eye relative to the length of the maxillary and presence of a red or yellow slash.

Sampling with electro-fishing techniques requires two or three people. One person carries the backpack electrofishing unit, while others net fish that are stunned by the electrical current. Specific conductance and temperature of the water should be measured and recorded before sampling (see Box 5.2 for guidelines on water temperature and specific conductance). Specific conductance provides information on how well water will conduct an electrical current and should be used in selecting electrofisher settings. Before sampling, a fine mesh net should be stretched across the downstream end of the habitat unit. This net serves to block stunned fish that may float downstream so that they may be captured and properly revived before release.

As with visual observations, the electrofishing crew enters a riffle or other habitat unit at the downstream end and proceeds upstream. The area of the habitat unit should be electrofished thoroughly, but excessive time should not be spent in small areas due to potential harm of exposing fish to the electrical field for extended periods (NOAA 2000). Fish that are stunned should be removed from the electrical field as quickly as possible and placed in a bucket containing fresh stream water. After the habitat unit has been completely sampled, fish collected are enumerated, allowed to recover and released.

Box 1.2. Stream electrofishing guidelines (from NOA, 2000).

Initial Site Surveys and Equipment Settings

1. In order to avoid contact with spawning adults or active redds, researchers must conduct a careful visual survey of the area to be sampled before beginning electrofishing.
2. Prior to the start of sampling at a new location, water temperature and conductivity measurements should be taken to evaluate electroshocker settings and adjustments.
3. No electrofishing should occur when water temperatures are above 18°C or are expected to rise above this temperature prior to concluding the electrofishing survey. In addition, studies by NMFS scientists indicate that no electrofishing should occur in California coastal basins when conductivity is above 350 µS/cm.
4. Whenever possible, a block net should be placed below the area being sampled to capture stunned fish that may drift downstream.
5. Equipment must be in good working condition and operators should go through the manufacturer's preseason checks, adhere to all provisions, and record major maintenance work in a logbook.
6. Each electrofishing session must start with all settings (voltage, pulse width, and pulse rate) set to the minimums needed to capture fish. These settings should be gradually increased only to the point where fish are immobilized and captured, and generally not allowed to exceed conductivity-based maxima (Table 5.1). Only direct current (DC) or pulsed direct current (PDC) should be used.

Table 1.1. Guidelines for initial and maximum settings for backpack electrofishing.

	Initial settings	Maximum	settings
Voltage	100 V	Conductivity (uS/cm)	Max. Voltage[2]
		<100	1100
		100–300	800
		>300	400
Pulse width	500 us		5 ms
Pulse rate[1]	30 Hz		70 Hz

[1] In general, pulse rates > 40 Hz will injure more fish than rates < 40 Hz.
[2] In California coastal streams, settings should never exceed 400 volts and electrofishing should not occur if conductivity is greater than 350 µS/cm.

Electrofishing Technique

1. Sampling should begin using straight DC. Remember that the power needs to remain on until the fish is netted when using straight DC. If fish capture is unsuccessful with initial low voltage, gradually increase voltage settings with straight DC.
2. If fish capture is not successful with the use of straight DC, then set the electrofisher to lower voltages with PDC. If fish capture is unsuccessful with low voltages, increase pulse width, voltage, and pulse frequency (duration, amplitude, and frequency).

Box 1.2 (continued).

3. Electrofishing should be performed in a manner that minimizes harm to the fish. Stream segments should be sampled systematically, moving the anode continuously in a herringbone pattern (where feasible) through the water. Voltage gradients may be high when electrodes are in shallow water where boundary layers (water surface and substrate) tend to intensify the electrical field.
4. Do not electrofish in one location for an extended period (e.g., undercut banks) and regularly check block nets for immobilized fish.
5. Fish should not make contact with the anode. Remember that the zone of potential injury for fish is 0.5 m from the anode.
6. Electrofishing crews should be generally observant of the condition of the fish and change or terminate sampling when experiencing problems with fish recovery time, banding, injury, mortality, or other indications of fish stress.
7. Netters should net fish quickly and not allow the fish to remain in the electrical field any longer than necessary.

Sample Processing and Recordkeeping

8. Fish should be processed as soon as possible after capture to minimize stress. This may require a larger crew size.
9. All sampling procedures must have a protocol for protecting held fish. Samplers must be aware of the conditions in the containers holding fish; air pumps, water transfers, etc., should be used as necessary to maintain safe conditions. Also, large fish should be kept separate from smaller prey-sized fish to avoid predation during containment.
10. Use of an approved anesthetic can reduce fish stress and is recommended, particularly if additional handling of fish is required (e.g., length and weight measurements, scale samples, fin clips, tagging).
11. Fish should be handled properly (e.g., wetting measuring boards, not overcrowding fish in buckets, etc.).
12. Fish should be observed for general condition and injuries (e.g., increased recovery time, dark bands, apparent spinal injuries) and be completely revived before releasing at the location of capture. Every attempt should be made to process and release ESA-listed specimens first.
13. Pertinent water quality (e.g., conductivity and temperature) and sampling notes (e.g., shocker settings, fish condition/injuries/mortalities) should be recorded in a logbook to improve technique and help train new operators.

Numbers of juvenile salmonids observed during visual surveys and captured during one-pass electrofishing can be used to provide and index of abundance. When divided by the area of habitat sampled, this index of abundance can be expressed as a density estimate (number/m2). However, neither is equivalent with a population estimate.

B. Estimating Population Size

Estimating the size of a juvenile salmonid population requires additional sampling and analysis. The additional sampling is essentially devoted to validating assumptions about the efficiency of visual observations (Hankin and Reeves 1988). Added analyses are needed to extrapolate estimates from a sub-sample of habitats to the entire area represented by that type of habitat.

Steps in estimating population size from systematic random samples.

1. Complete a survey of habitats available within the stream or reach of interest, as described in Box 5.1.
2. Complete snorkel surveys as described on pages 3 –6.
3. Draw a systematic random sample of habitats in which visual observations were made. This sample should include at least 10 units from each habitat type.
4. Conduct 3 – 5 pass depletion electrofishing in each of these habitat units and calculate the number of juvenile salmonids of interest (Y_T) as:

   $Y_T = M_0 * \Sigma Y_i / \Sigma M_i$, where M_0 = the total size of all habitat units, M_i = the size of the primary habitat unit, and Y_i = total number of the fish species being sampled in unit M_i. An estimate of precision for this estimate of abundance is presented in Hankin (1984).
5. A ratio for calibrating the diver visual observations with the more accurate electrofishing samples results is calculated as:

   $R = \Sigma Y_T / \Sigma D_T$, where the sum applies to T = 1 – n', n' = the number of habitat units in which both diver counts and electrofishing estimates are made, and D_T = the mean count by two divers in habitat unit T.
6. For habitat units in which only diver counts were recorded, use the calibration ratio to correct for visual uncertainty:

   $Y_T = R * D_T$
7. Last, the total number of fish in all units of a specific habitat type is estimated from:

   $Y_{hat} = N * \Sigma Y_T / n$, where N = the total number of units of the specific habitat type and n = the total number of units in which diver counts have been made.

While the above calculations seem tedious, they are needed to produce a statistically valid population estimate and satisfy the assumptions of sampling theory.

IV. Considerations Before Sampling

Natural variability

Number of juvenile salmonids present varies among reaches, seasons and years within a single stream and among different streams. We sampled juvenile steelhead in Bull Creek, Humboldt County, during August 2002 to test how variable results of abundance and population estimates would influence ability to detect change.

The area sampled included the lower 2.5 km of Bull Creek, beginning at the streams confluence with the South Fork Eel River. We stratified this section into three stream reaches, based on visual observation of habitats and stream gradient. Habitat was classified for 96 units covering the entire 2.5 km and measurements of area recorded for each habitat unit (Table 5.2).

Table 1.2. Summary of habitat area in three reaches of Bull Creek, Humboldt County, during August 2002.

	Lower	Middle	Upper
Number Run Units	7	6	15
Mean Area (m^2)	196	140	147
S.D. of Mean	82	98	88
Σ Area (m^2)	1,373	839	2,202
% Area	21.8	17.6	49.9
Number Pool Units	8	17	10
Mean Area (m^2)	448	127	125
S.D. of Mean	308	81	72
Σ Area (m^2)	3,587	2,152	1,246
% Area	56.9	45.0	28.2
Number Riffle Units	8	14	11
Mean Area (m^2)	168	128	88
S.D. of Mean	141	99	55
Σ Area (m^2)	1,342	1,788	965
% Area	21.3	37.4	21.9

For fish sampling, we selected a random sample consisting of 25% of the total habitat units. These habitat units were sampled entirely by 3-pass depletion electrofishing to insure accurate estimates of density were made, density and population size calculated as described above. Density estimates increased from the lower reach to the upper reach, while population size was greatest in the middle reach (Table 5.3).

Table 1.3. Mean density (+ S.D.) and population size (+ S.D.) of juvenile steelhead in three reaches of Bull Creek, Humboldt Count, during August 2002.

	Lower	Middle	Upper	All
Mean Density (m^2)	0.10	1.86	2.01	1.34
S.D. of Mean	0.09	0.68	0.77	1.04
Population Estimate	401	9296	8098	
S.D. of Population Estimate	77	1017	875	

We used power analysis to evaluate the ability of both density estimates and population size to detect change over years of sampling (Gibbs 2003). In analyzing density estimates, we evaluated three amounts of sampling effort. First, we evaluated the power of the total of 25 samples from Bull Creek change over time, we then randomly eliminated one-third of the samples and repeated this analysis, and last, we randomly eliminated another one-third of the samples and repeated the analysis.

Conditions we assumed were that samples for monitoring would be collected once each year and that the coefficient of variation among years was 50% (a CV we calculated for coho salmon abundance in Prairie Creek was 51% over four years). We set α at 0.10, and ran 500 iterations of a 2-tailed t-test to estimate how many years of sampling would be required to detect change at a desired power level of 0.80. Results from this analysis suggest that change, under these conditions, can be detected after three years of sampling with 17 samples, and that increasing sample size adds little to the ability to detect change (Figure 5.1). With only nine samples, the ability to detect change under these conditions is delayed to five years.

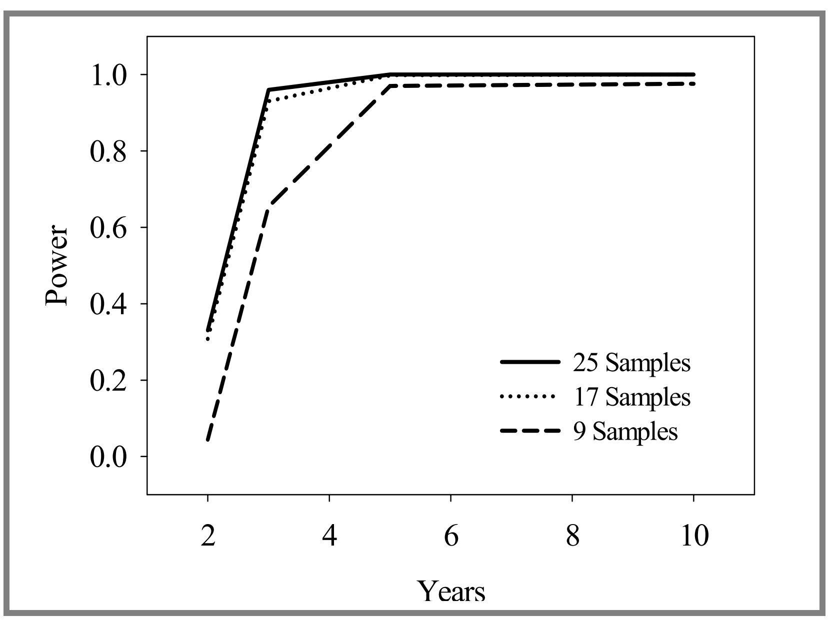


Figure 1.1. Power to detect a 10% increase in density of juvenile steelhead within a 2.5 km portion of Bull Creek, Humboldt County, California, with a sampling effort of 9, 17 and 25 randomly selected habitats per year.

In evaluating population estimates, we used the same assumptions and employed the same statistical technique as for density estimates. Results suggest that a 10% increase in population size in the lower reach could be detect in five years, but detecting the same change in the middle and upper reaches would require about eight years (Figure 5.2).

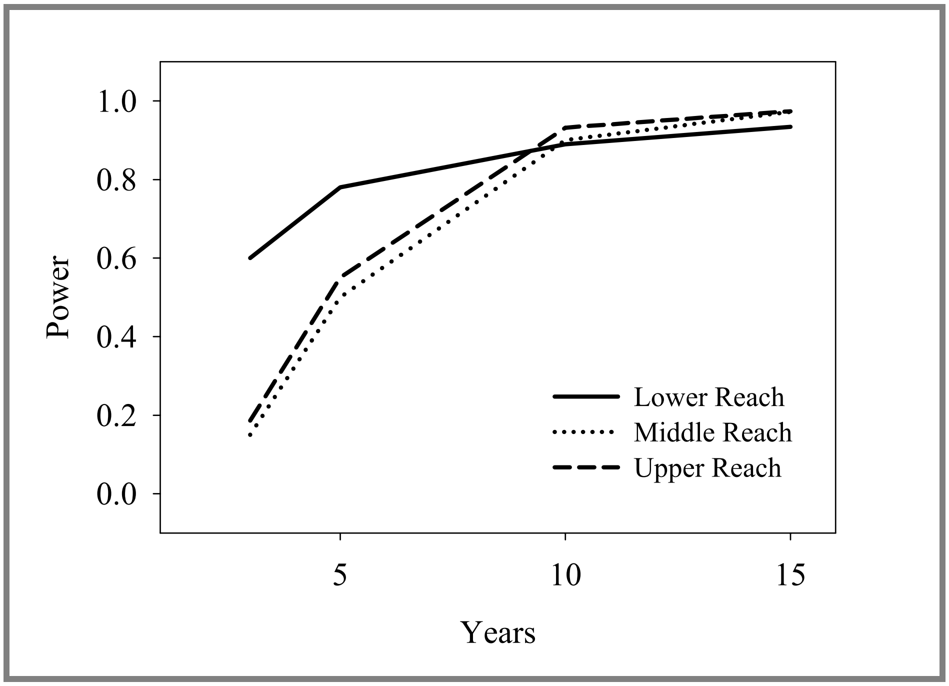


Figure 1.2. Power to detect a 10% increase in the population size of juvenile steelhead within the lower, middle and upper third of a 2.5 km portion of Bull Creek, Humboldt County, California.

V. Quality Control and Quality Assurance
Quality assurance and quality control procedures should be established before juvenile salmon and steelhead sampling. These procedures should include elements of the following:

Training that addresses,
1) safety practices in both stream snorkeling and electrofishing,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) recognition of fish when diving.

The quality assurance plan for data entry and management should include,
1) data entry
2) data management
3) data analysis
4) chain of custody for data

The assurance for fish sampling should include independent assessment of efficiency. This might include;

1) independent divers sampling a percentage of habitats previously sampled and
2) independent observers participating in electrofishing (we hesitate to recommend added electrofishing due to the potential for added stress on fish).

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

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2. SALMON AND STEELHEAD PRESENCE

I. Rational

The presence of salmon or steelhead in a stream, or reach of stream, can be used to validate some restoration actions. It is obviously a measure that could be employed to validate whether or not removing barriers to migration was successful. Presence surveys may also have application in severely degraded streams that no longer support salmon or steelhead.

II. Limitations

Determining whether or not a species is present in a stream or watershed is not always an easy task. Indeed, one of the sources of uncertainty in monitoring programs is the ability to detect the animal of interest (MacKenzie et al. 2002). Our ability to detect the presence of salmon and steelhead varies with life stage, sampling method and location. For example, while adult salmon and steelhead are much larger than juveniles, their presence in streams is most often restricted to periods when visibility in streams is limited. In contrast, although juvenile salmon and steelhead are relatively small they are more numerous than adults and most are present in streams during periods when water is low and clear.

The Department of Fish and Game is currently investigating the statistical distribution of juvenile salmon and steelhead that will provide guidance on presence or absence surveys. In the interim, we propose a presence method similar to one currently employed by the Department of Fish and Game. The method we describe can be easily modified when statistical information on the probability of detecting different species has been developed.

III. Sampling Methods

The primary sampling method recommended is visual observation using snorkel gear. This method is less costly and intrusive than other methods. However, visual observation techniques are not possible in all types of habitats, nor are they applicable all streams. Electro-fishing is recommended in situations where visual observation is either not possible or would provide inaccurate results. Methods for electro-fishing are described in the section on abundance.

Systematic random sampling should be used in surveys for the presence of juvenile salmon or steelhead (Hankin and Reeves 1988). Sampling effort may vary with the area of stream to be sampled. All pool and run habitats should be sampled if the stream reach is less than 200 or 300 m long. In sampling large reaches or entire streams, samples should be randomly distributed within the area of interest. The randomization process should also be repeated for each type of habitat type and proportion of units selected for sampling can differ among habitat types. For example, a systematic random sample for 20% of the pool habitats can be achieved by drawing a random starting number between 1 and 5. If the starting random number for pool habitats in this example was 2, then the 2nd, 7th, 12th and 17th, etc. pool habitat should be sampled until the survey area has been covered. This process should be repeated for run habitats and any other habitats that might be defined, but we do not recommend visual observation methods in riffle habitats.

Divers should practice in two pool or run habitat in a stream having the juvenile salmonid species presence surveys are intended to detect. This practice allows divers' to familiarize themselves with the species and size classes of salmonids they may likely encounter in the stream to be surveyed. Ages and size classes of salmonids can very among streams during any season because of differences in time of emergence and growth.
Identification of all species can be problematic within the range of coastal cutthroat trout. Juvenile steelhead and cutthroat trout cannot be consistently distinguished until the reach a length of around 80 mm fork length (Figure 5.1). Thus, from the Eel River northward, small trout should be counted as age 0+ trout species. Steelhead and cutthroat trout > 80 mm FL can usually be assigned to age 1+ of their species. However, these species should be recorded as age 1+ trout if divers are not confident in their ability to separate these species.

Visual observations of pre-selected pool, deep pool and run habitats are conducted, progressing from downstream to upstream. Divers should enter the downstream end the habitat unit to be surveyed. They should move upstream, parallel to one another, through the habitat unit using deliberate movements so as to minimize disturbance to fish. Fish are counted as divers move upstream and recorded using either a hand counter or underwater record slate. Using a recording device is especially important where fish are abundant and where multiple species occur. After completing the census for a specific habitat unit, data are recorded in small "Write-in-the-Rain" or plastic paper notebooks than can be carried in a dive pouch.

Visual observation methods are not possible in riffle habitats and may not be effective for entire reaches of some shallow streams. Furthermore, cobble and other obstructions in riffle and other shallow habitats also make seine netting inefficient. These habitats must be sampled using electro-fishing techniques described in the section on abundance and population estimates.

It may be necessary to sample an individual habitat unit a second time if both divers are not confident in their results or the habitat unit is disturbed. At least 20 minutes should elapse between the completion of one dive and the beginning of a second. This time allows frightened fish a period to settle down and reoccupy microhabitats.

IV. Considerations Before Sampling

Natural variability

Habitats and reaches of streams occupied by juvenile salmon and steelhead may vary from year to year as water conditions vary. However, we are not aware of any published information on the probability of detecting juvenile salmonids relative to abundance. The Department of Fish and Game is presently supporting efforts to develop this kind of information and further guidance may be provided in the future.

V. Quality Control and Quality Assurance

Quality assurance and quality control procedures should be established before juvenile salmon and steelhead sampling. These procedures should include elements of the following:

Training that addresses,

1) safety practices in both stream snorkeling and electrofishing,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) recognition of fish when diving.

The quality assurance plan for data entry and management should include,

1) data entry
2) data management
3) data analysis
4) chain of custody for data

The assurance for fish sampling should include independent assessment of efficiency. This should include re-sampling 5% of all habitat units by a second snorkel survey team. The second dive team should;

1) not have access to the survey results of the first team data to avoid bias,
2) should use methods identical to the first dive team, and
3) conduct the second dive within one week of the first dive.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

Hankin, D.G. 1984. Multistage sampling designs in fisheries research: applications in small streams. Canadian Journal of Fisheries and Aquatic Sciences 41: 1575-1591.

MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle and C.A. Langtimmm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

3. Juvenile Salmon and Steelhead Condition

I. Rational

Length and weight of fish is commonly used as a management tool in inland fisheries. Relationships between length and weight in fish have been mathematically expressed as various ways as condition factors (Blackwell et al. 2000). Condition factors express the predicted weight or plumpness of a fish at a given length. Until recently, however, limitations imposed by the statistical properties of length and weight relationships prevented their use in comparisons of populations. The development of a "relative weight" index (Murphy et al. 1990) appears to have overcome these statistical limitations and presents potential for comparing condition among different populations. Condition has been used as a surrogate for fish body composition, as a measure of fish health and to assess productivity or prey available (Blackwell et al. 2000).

Weight of juvenile Pacific salmon and steelhead has not been routinely recorded in the past. Recording weight of small live fish in the field was difficult with earlier technology, and many saw limited use in these data. Consequently, condition indices for these Pacific salmon and steelhead have not been calculated. However, improvements in portable electronic balances now offer the opportunity to collect precise measurements to the 1/100th of a gram in the field.

We propose to develop relative weight indices for juvenile coho salmon and steelhead. Both species use freshwater habitats for a year or more and condition of these species should reflect productivity of habitat. Assuming productivity is correlated with habitat quality, condition indices may provide a tool for measuring the response of juvenile salmonids to habitat.

II. Limitations

The primary limitation of this method is that it has not been applied to juvenile Pacific salmonids. Therefore, the relative weight index must be developed, tested and peer reviewed before being an acceptable measure.

Development of a relative weight index or equation requires gathering data from broad areas that reflect all conditions the species might encounter. Based on previous experience, Murphy and his colleagues (1990) recommend gathering length and weight information from 50 or more populations across the range of a species. We now have data for 44 populations of juvenile coho salmon ranging from California to Alaska. Below we present preliminary results in developing a relative weight equation for this species. At present, we have fewer data for juvenile steelhead.

III. Sampling Methods

Gathering data essential to calculating relative weight is easy and can be combined with other methods that produce a sample of juvenile salmonids. Electrofishing, minnow trapping and seining all should produce reliable data. The objective in sampling should be to obtain measurements that reflect the current range in size of the species being sampled.

After capture, fish should be anesthetized using tricane methanesulfonate (MS222), clove oil or Alka Seltzer in cool oxygenated water. Human health concerns have been raised over chronic exposure to MS222, therefore any personnel using this agent should be familiar with cautions explained on the material safety data sheet accompanying the product and should take appropriate precautionary measures. Effectiveness of anesthetic agents varies with concentration of the agent, water temperature, and fish density. Those using anesthetics should be familiar with dosage recommendations. Oxygenated, cool water should be provided to fish being held before anesthesia and those recovering from anesthesia.

Measurements of length should be recorded to the nearest 1.0 mm and measurements of weight should be recorded to the nearest 0.01 g, wet weight.

IV. Considerations Before Sampling

The relative weight index for juvenile coho salmon has not been fully developed. Therefore guidance on variability and the number of samples needed is not possible. However, most populations sampled to date exhibit similar length weight relationships (Figure 1.1, Table 1.1).

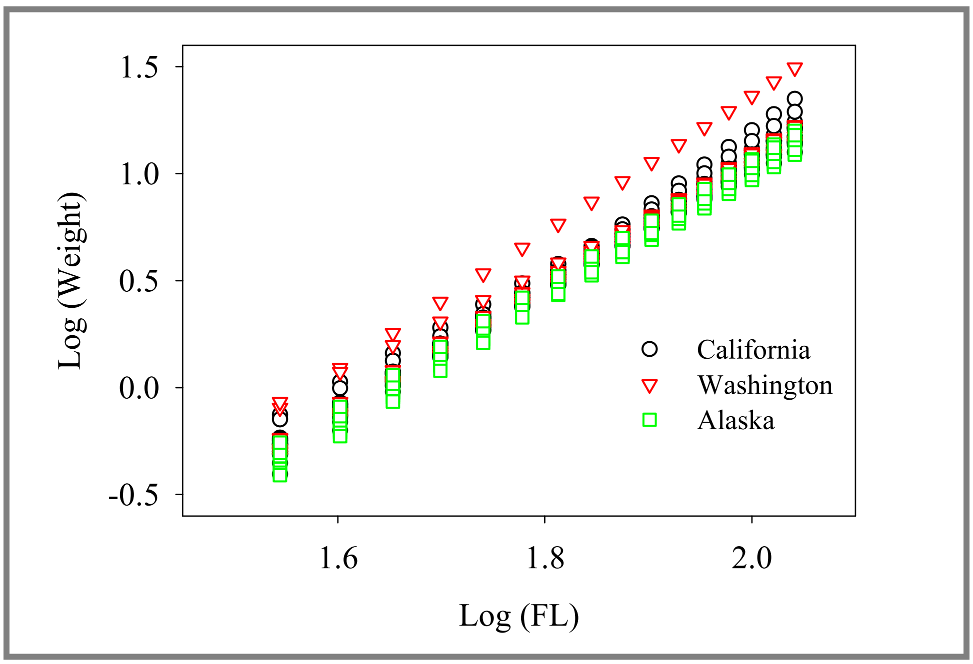

Figure 1.1. Predicted log of weight at 5 mm log length intervals for 44 populations of juvenile coho salmon from California, Washington and Alaska.

Table 1.1. Populations of juvenile coho salmon, their location and log length log weight parameters.

Location	Water Body	Year	n	a	b	R^2
CA	Lindsay Creek	1998	35	-4.1605	2.6134	0.979
CA	Lindsay Creek	1999	50	-5.1213	3.1127	0.972
CA	W.F. Sproul Creek	1998	30	-4.9495	3.0329	0.983
CA	W.F. Sproul Creek	1999	152	-5.0045	3.0466	0.934
CA	Hollow Tree Creek	1998	30	-4.0231	2.5092	0.950
CA	Casper Creek	1998	40	-4.8349	2.9617	0.944
CA	Casper Creek	1999	144	-4.6044	2.8302	0.893
CA	Freshwater Creek	1998	68	-4.7947	2.9433	0.976
CA	Freshwater Creek	1999	199	-4.7808	2.9034	0.905
CA	Sharber Creek	1999	113	-5.8512	3.5269	0.902
CA	S.F. Broken Kettle Creek	1999	88	-5.4501	3.3014	0.900
CA	Redwood Creek	2001	34	-4.8456	2.9373	0.954
CA	Prairie Creek	1999	118	-4.6938	2.8710	0.963
CA	Prairie Creek	2000	204	-4.5408	2.7853	0.928
CA	Prairie Creek	2001	157	-4.9330	3.0110	0.976
CA	Streelow Creek	2001	100	-4.7511	2.9170	0.962
CA	Boyes Creek	2001	74	-4.6261	2.8221	0.984
WA	Forks Creek	1995	310	-5.0939	3.0868	0.931
WA	Forks Creek	1996	288	-4.7211	2.9045	0.947
WA	Forks Creek	2001	189	-5.0667	3.0827	0.967
WA	Forks Creek	2002	169	-5.3012	3.1967	0.980
WA	Herrington Creek	1997	49	-4.7332	2.9111	0.975
WA	Herrington Creek	1998	37	-3.8069	2.4218	0.806
WA	Herrington Creek	1999	66	-4.7759	2.8981	0.994
WA	Herrington Creek	2000	141	-5.0962	3.0951	0.973
WA	Huckelberry Creek	2001	110	-4.7496	2.8907	0.975
WA	Huckelberry Creek	2002	91	-4.8550	2.9525	0.974
AK	Ken’s Pond	1995	879	-5.0989	3.0700	0.959
AK	Lost Pond	1995	239	-4.9822	3.0129	0.966
AK	25 Mile Pass Creek	1995	482	-4.7851	2.8819	0.946
AK	E.F. Slippery Lake Creek	1988	254	-5.2272	3.1393	0.982
AK	E.F. Slippery Lake Creek	1989	360	-4.9217	2.9676	0.903
AK	E.F. Slippery Lake Creek	1990	95	-4.8252	2.9426	0.952
AK	E.F. Slippery Lake Creek	1991	38	-4.4809	2.7339	0.946
AK	Saginaw Creek	1989	182	-4.7548	2.8930	0.981
AK	Saginaw Creek	1994	116	-4.9326	2.9904	0.977
AK	Saginaw Creek	1995	170	-5.3431	3.2050	0.988
AK	Maybeso Creek	1999	481	-4.7709	2.9154	0.915
AK	Maybeso Creek	2000	46	-4.7739	2.8716	0.958
AK	Kake Bake Creek	1983	174	-4.8790	2.9511	0.974
AK	Kake Bake Creek	1984	81	-4.7649	2.8789	0.984
AK	Staney Creek	1996	220	-4.8772	2.9610	0.979
AK	Tonalite Creek	1989	38	-5.2746	3.1514	0.970
AK	Tonalite Creek Pond	1999	166	-4.7180	2.8888	0.973

V. Quality Control and Quality Assurance

Quality assurance and quality control procedures should be established for each salmon and steelhead smolt trapping program. These procedures should include elements of training, data entry and management, and independent assessment of methods.

The training program should address:

1) safety practices for handling anesthetic agents,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) data entry and management.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

Blackwell, B.G., M.L. Brown and D.W. Willis. 2000. Relative weight (Wr) status and current use in fisheries assessment and management. Reviews in Fisheries Science 8:1-44.

Murphy, B.R., M.L. Brown and T.A. Springer. 1990. Evaluation of the relative weight (Wr) index, with new application to walleye. North American Journal of Fisheries Management 10:85-97.

4. Juvenile Steelhead Age

I. Rational

Age of juvenile steelhead may be a useful measure for detecting a response to watershed restoration for several reasons. First, juvenile steelhead are widely distributed in coastal watersheds of California. Second, juvenile steelhead spend multiple years in fresh water before smolting and migrating to the ocean. Third, smolt transformation in salmonids is regulated, in part, by size and will not occur if a fish has not reached some critical size (Groot et al. 1995). Finally, use of juvenile steelhead age as a watershed response measure assumes that growth is related to habitat condition.

The rational for using age of juvenile steelhead as a measure for detecting a response to watershed restoration is that growth will be slower under poor habitat conditions. With slower growth, more time will be required to reach the critical size for smolting, resulting in fish being older at the time of smolting. Extending this assumption, growth would hasten as restoration actions improve habitat conditions until age at smolting is eventually reduced.

II. Limitations

While intuitively appealing, the assumption that growth is related to habitat quality has not yet been rigorously tested. Multiple environmental factors such as water temperature, food available and density of juvenile salmonids influence growth and may present insurmountable obstacles in establishing a relationship between habitat and growth. We propose to test this assumption as part of the process of validating protocols for assessing watershed restoration.

III. Sampling Method

Juvenile steelhead for aging can be acquired from the distribution and abundance, presence sampling methods described, or by any method that produces fish-in-hand. After a collection of fish has been obtained, two basic methods are available for age determination. First, one may use hard structures such as otoliths or scales to assign ages to individual fish (Frie 1982). Second, one may analyze the size distribution of populations for indications of age groupings (Nielsen and Johnson 1983). We propose a combination of these two methods be used (Box 4.1).

Text Box 4.1. Assigning ages to juvenile steelhead.

Determining age structure of juvenile steelhead population.

1) Obtain a sample of fork lengths, in mm, from 100 or more juvenile steelhead.
2) Collect a scale sample from 20% or more of the individual fish distributed across 10 mm length categories.
3) Count the number of fish in each 10 mm length category and plot this length frequency distribution.
4) Identify modes in the distribution and assign ages to each mode.
5) Determine the age of individual fish from scale samples and use these data to verify age modes as well as the uncertainty between ages.
    a. Scales should be collected from mid-way between the back of the dorsal fin and the lateral line.
    b. Collect 3-6 scales from each fish since some may present difficulties in aging due to false annuli, and other anomalies.
    c. Mount the scales between two microscope slides and view them through a microscope or micro-fish reader.

Age distributions can sometimes be easily distinguished from plotted data (Figure ..1). However, modes in distribution that are well separated are often the result of too few samples being collected. With adequate sample sizes, all size ranges are typically represented and there is some overlap in size at age between modes (Figure x.2). This overlap presents difficulty is assigning ages, but we are less concerned with the total number of fish in each age category than we are with the age at smolting. If with the total number of fish in each age category is considered important, statistical methods may be employed to assign ages to individuals of size at age overlaps (Nielsen and Johnson 1983).

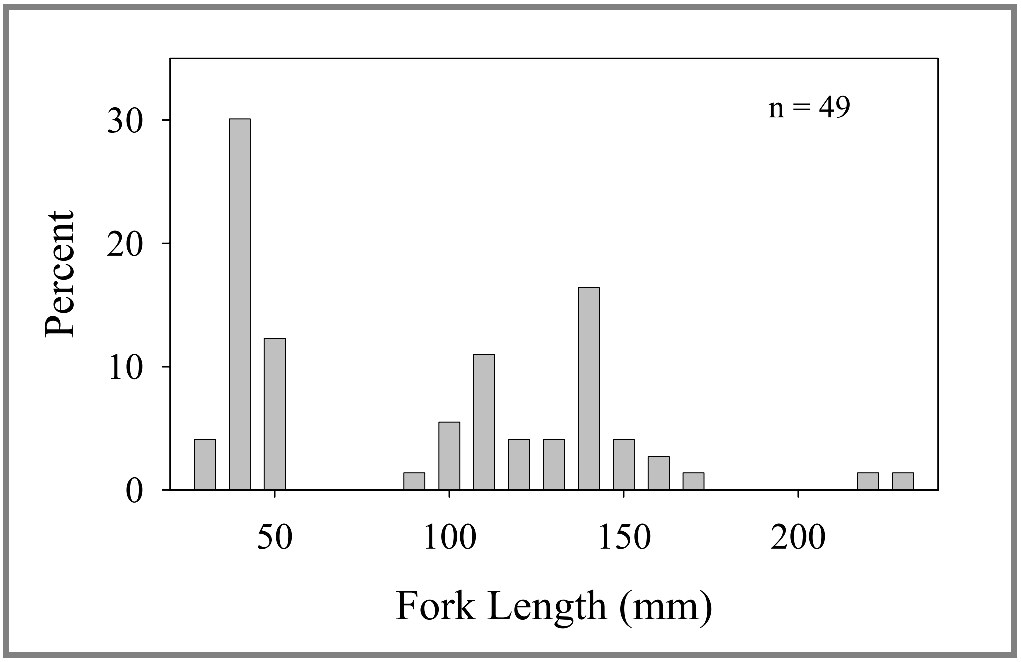

Figure 4.1. Length frequency distribution of juvenile steelhead from South Fork Roach Creek, Humboldt County, California during July 2002.

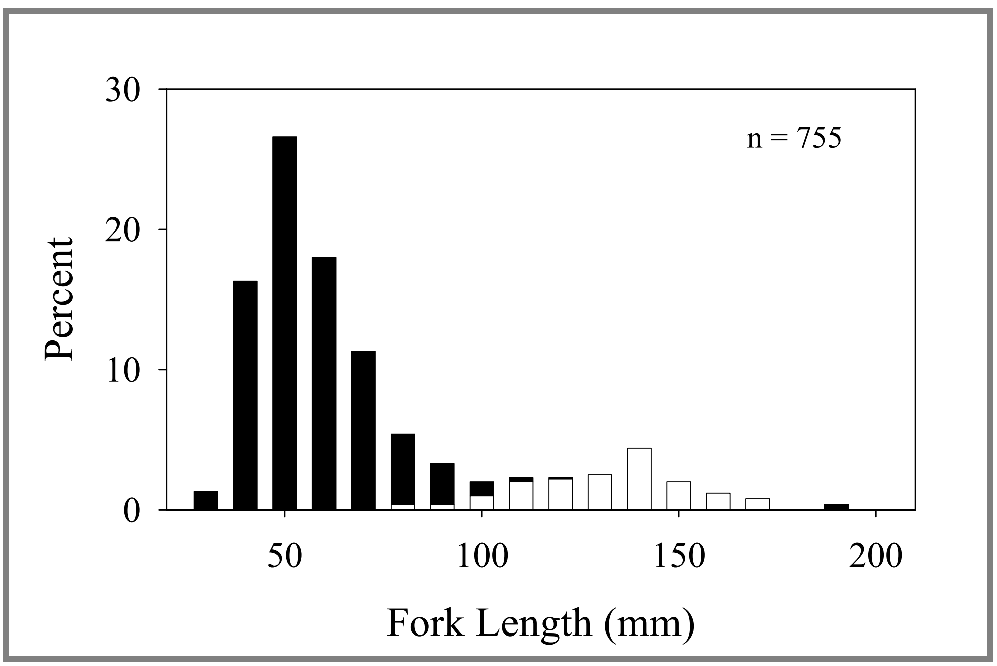

Figure 4.2. Length frequency distribution of juvenile steelhead from Bull Creek, Humboldt County, California during August 2002.

IV. Considerations Before Sampling

We are presently evaluating this method. When analyses are complete, we will evaluate the statistical properties of age data and provide guidance on their variability and ability to detect change.

V. Quality assurance and quality control

Quality assurance and quality control procedures should be established for aging juvenile steelhead. These procedures should include elements of training, data entry and management, and independent assessment of methods.

The training program should address:

1. identification of fish species likely to be encountered,
2. proper handling of fish,
3. scale sampling and
4. assigning ages to scales. .

QA/QC procedures in assigning ages to scales should include the verification of 5 – 10% of the original ages. That is, a second person or persons without knowledge of ages assigned, reads scales previously aged and determines ages independently.

VI. References

Frie, R.V. 1982. Measurement of fish scales and backcalculation of body lengths using a digitizing pad and microcomputer. Fisheries 7:5-8.

Nielsen, L.A., and D.L. Johnson (Eds.). 1983. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

5. Salmon and Steelhead Smolt Production

I. Rational

Smolt production is defined as the number of salmon or steelhead smolts migrating from a stream toward the ocean. Smolt production is typically measured by capturing migrants using traps. This measure is most often applied to coastal populations of coho salmon or steelhead because each species resides in freshwater habitats one or more years before undertaking ocean migration. Juvenile Chinook salmon from interior populations, such as those spawning in the upper Klamath River, may also remain in fresh water for up to a year before beginning their migration to the ocean. Data on production of salmon or steelhead smolts leaving a stream can provide information on freshwater survival and, by inference, habitat quality. When combined with estimates of the numbers of adults returning to spawn, it can also be used to calculate ocean survival.

II. Limitations

Several problems limit the use of smolt production data in assessing watershed response to restoration. The first of these is that it cannot be applied to all species of salmonids. Trapping juvenile chinook salmon leaving coastal streams does not provide information on smolt production. Populations of coastal Chinook salmon migrate from their natal streams as fry, then rear and undergo smoltification in lower rivers or estuaries before entering the Pacific Ocean during summer or fall. Smolt production is also not applicable to coastal cutthroat trout since this species exhibits a variable period of freshwater residence before ocean migration, or may not use the ocean environment.

A second limitation arises from criteria necessary for operating a trap to capture migrating smolts. Sites selected for migrant smolt trap placement should be located near the lower end of the basin so as to provide an estimate of the number of smolts leaving, the gradient should be relatively low and the stream should not be very large nor very small. While rotary screw traps can be deployed in large rivers, errors associated with efficiency estimates usually prevent estimates of smolt production. When considering watersheds, these criteria reduce or eliminate the element of randomness that is desirable in sampling. However, streams could be randomly selected for smolt trapping within regions that encompass multiple watersheds.

III. Considerations Before Sampling

Natural variability and number of samples

Number of migrating salmonid smolts captured within a stream varies with season, discharge, and probably day length. In 2002, we estimated that 5,245 coho salmon smolts were produced in upper Prairie Creek in Humboldt County. Smolts were captured from late February through May, but 58% of the total catch occurred during a two week period in April. At a site 6 km downstream, this peak in smolt timing was about one month later and smolts were present until June when trapping was discontinued.

We applied power analysis to data from this site to estimate the number of years needed to detect a change in production. Our analysis assumed that trend in abundance had a coefficient of variation of 50%, less than the 66% variation observed at this site over 4 years. Our analysis suggests a minimum of 10 years of monitoring at this site would be required to detect a 10% change in production with power of 0.80 and $\alpha = 0.10$ (a 10% probability of being wrong), even with our conservative assumption (Figure 5.1).

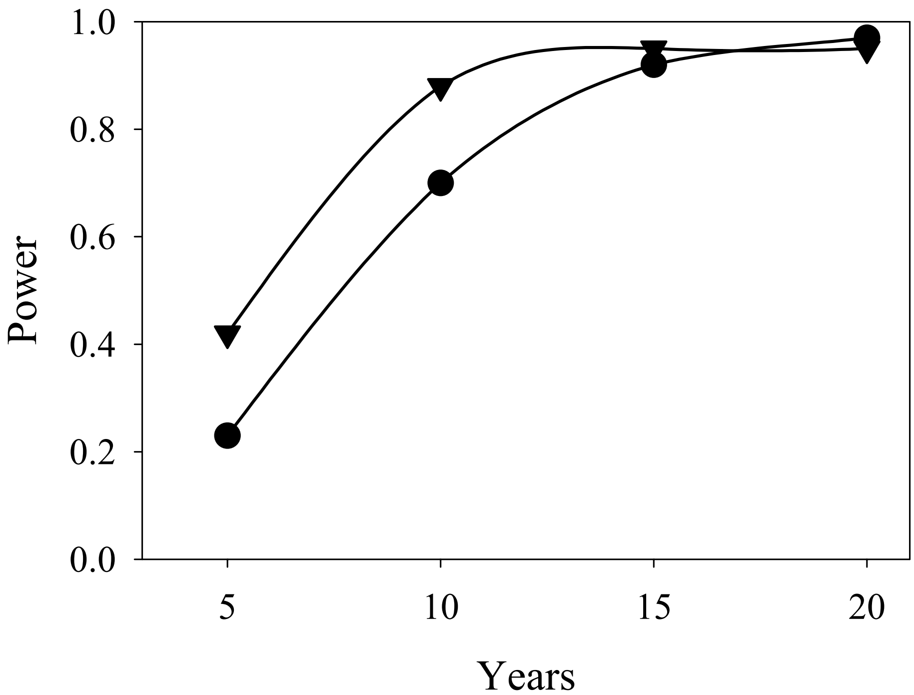

Figure 5.1. Power to detect a 10% increase (circles) or 10% (triangles) decrease in number of coho salmon smolts from an immigration trap. Data are calculated from one trap having average catch 13 smolts per day (S.D. $\pm$ 10.3) and assuming a trend coefficient of variation of 50%.

Variability in smolt production estimates typically is greater among streams than within. Coefficients of variation in coho salmon smolt production among streams are typically 50% – 120% of the average (Keeley and Walters 1994). In 2002, the coefficient of variation among three streams from Redwood National Park, California was 114% of the mean and varied from 17 – 41% of the mean within streams. Again, we applied power analysis to these data to determine the number of samples needed to detect a difference in production from a watershed. Again, our analysis suggested that to detect a 10% change with power of 0.80 and $\alpha = 0.10$ would require 10 traps operating for 10 years (Figure 5.2).

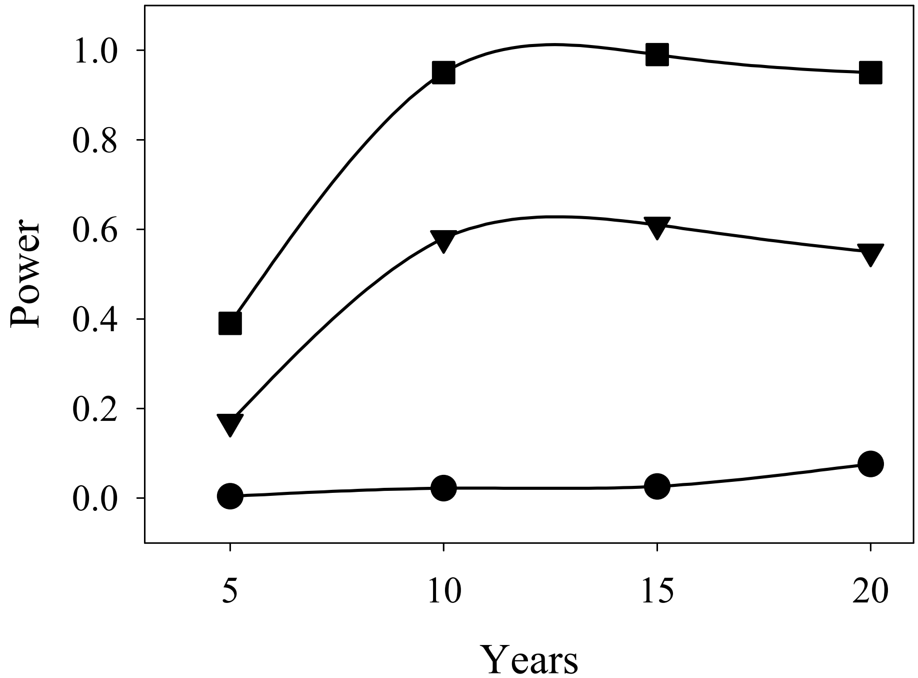

Figure 5.2. Power to detect a +10% difference in the number of coho salmon smolt from a theoretical watershed having three (cicles), five (triangles) and ten (squares) immigration traps. Data are calculated from multiple traps operated in Redwood National Park, California during 1999 - 2002 and assuming a trend coefficient of variation of 50%.

IV. Sampling Methods

Personnel and training

The labor needed to operate a smolt trap varies with the type of data being collected. Installing a trap or later removing a trap requires four people for four – six hours. After installation, one person can process the sample if only the number of smolts captured is being recorded. However, for safety reasons we recommend that two people be assigned to smolt trap sampling. A two person crew can also record size of smolts and collect scale samples for later aging, if desired. Personnel conducting the sampling should be posses a minimum set of biological skills:

1) All personnel should be competent in identifying juvenile salmonids.

2) All personnel should be trained in procedures to anesthetize juvenile salmonids.

All personnel should be trained to handle juvenile salmonids and, other fish, in a manner that does not induce undue stress. Proper handling is necessary for identification when multiple species are present and for marking individual fish to be used in trap efficiency testing.

Gear needed
Salmon and steelhead smolts migrating downstream may be captured using traps of various design. The most common are traps fyke net, inclined plane or rotary screw traps.

Fyke net traps consist of a fyke net having a live box attached to the cod end. In smaller streams, the fyke net can be fitted with wings and effectively cover all or most of the stream. Smolts are carried into the net and live box by the current.

Inclined plane traps are constructed from rigid material and have a large rectangular opening that leads to a smaller opening at the live box (Figure 6.3). Inclined plane traps may be fished with the trap mouth resting on the stream bottom, or they can be fitted with pontoons and fish off bottom in larger streams (Todd 1994). Again, smolts are carried into the net and live box by the current.

Rotary screw traps consist of a cone covered with screen and having an archemedes screw built into the cone. The trap is suspended on pontoons with the larger end of the cone facing upstream and adjusted so that the lower half of the cone is in the water. Water pressure forces the cone to turn on a central shaft and migrating smolts that enter the cone are trapped by the rotating screw and forced into a live box at the end of the trap. Rotary screw traps are better suited to larger streams and rivers having adequate flow to turn the cone and enough depth to float the trap.

None of these trap designs is appropriate for all streams or flow conditions. The type and size of trap used is both a function of the size and flow characteristics of the stream being sampled, and the size and species of the fish that are targeted for trapping. In general, the screw trap is more effective in larger streams, while the fyke net and inclined-plane traps are better suited to small or medium sized streams.

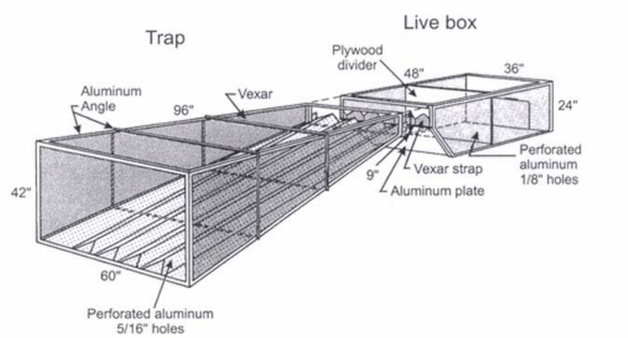

Figure 5.3. Image of inclined-plane trap without pontoons attached (From Todd 1994).

Selection of Sampling Locations
Sample locations should be selected on the basis of answering the question being asked. A reasonable question might be; have restoration projects within a sub-watershed resulted in greater numbers of smolts migrating from the sub-watershed? Locating a smolt trap as near the sub-watershed outlet as possible would provide the best data to address this question. General considerations in locating smolt traps are listed below.

- The stream being sampled should have spawning populations of steelhead, coho salmon or Chinook salmon.
- The stream should not be either so large or small that efficiency of the trap cannot be evaluated. Trapping sites should be located in streams as large as the gear will effectively sample since larger streams will usually yield more smolts. Size of streams in which various smolt trapping gear can effectively sample are generally second to fifth order and have an active channel width of no more than 30 m.
- Stream gradient should not be too great, a gradient of 1 – 2% is best. High gradient sites can result in high water velocity that may injure fry and smolts during trapping. Conversly, velocity in wide unconstrained channels may not be adequate to operate some types of traps.
- Depth of water is an important consideration in selecting sampling sites. Fyke net traps are limited to depths of 1 m or less. Rotary screw traps and inclined plane traps must be located at depths of 0.75 m or greater.
- Water velocity or flow (m/s) must be sufficient to carry fish into fyke net or inclined-plane traps. For rotary screw traps, a flow of 0.8-2.0 m/s has been observed to be sufficient to rotate the screw. At some sites, panels can be installed to direct water into traps. Stream flow should enter the trap on a straight line. Placing traps in bend pools or near obstructions that create eddys may cause fry to be impinged on trap surfaces.
- The stream substrate at the site should be relatively uniform. Presence of boulders and cobble will create turbulence that may limit trap efficiency or contribute to injury of fish.
- Access is an important consideration, both physical and legal access. Trapping sites should be near roads, particularly if operating a rotary screw or inclined plane trap. The site should also be located where a land owner is willing to allow access for long periods, 10 or more years.
- Finally, the site should be located where large trees or other suitable anchor sites are available on the stream side.

Operation of rotary screw or inclined-plane traps during high stream flow can result in mortality from debris jamming the net and live box. Fyke net traps cannot be fished during high stream flow, but can also become choked with debris during spates. In either case, a live box or trap choked with debris can result in mortality to both salmon smolts and fry. Therefore, smolt traps must be carefully monitored during times when flow is high or when excessive debris might be carried in the stream.

In operating smolt traps, care must be taken to minimize mortality. Predation by larger fish on smaller fish in the trap live box is common. Fern fronds or fir boughs are often placed in the trap live box to provide hiding cover for smaller fish. A v-shaped water current deflector is also often placed in trap live boxes constructed of plywood or metal. These v-shaped deflectors are intended to create a pocket of calm water for small fish. Our research suggests that neither of these techniques is particularly effective in reducing mortality of fry. Instead, we recommend a 2 m long, 1 m wide and 1 m high live box constructed of ¼ inch square knotless nylon netting. This trap live box is divided into forward and rear compartments by ¾ inch square knotless nylon netting and attached to the fyke net cod end using a 2 m length of 6 inch PVC pipe. The principle of this live box design is that the PVC pipe connector provides enough water velocity to carry small fish into the trap and through the dividing panel. Water velocity then quickly dissipates. Larger fish may be impinged on this panel briefly, but are strong enough to overcome the water velocity. Experimentation with this trap live box design has resulted in marked declines in mortality from predation (Reisburger in prep.)

Sampling duration and frequency

In California, migration of coho salmon and steelhead smolts may occurring from fall through summer, but peak migration for both species during most years is in April and May (California Cooperative Fish Research Unit 2002, Shapovalov and Taft 1954). Sampling for migrating smolts should begin in late February or early March and continue until the catch decreases, usually in early June. Traps are usually operated 24 hours per day seven days per week and must be monitored daily.

Estimating trap efficiency

No migrant smolt trap will sample 100 percent of the water column, therefore the number of smolts captured represents an unkown portion of the total number migrating downstream. Trap efficiency, the proportion of the total migrant population captured by the trap, is influenced by stream flow, fish species, size and behavior. And, most of these variables change during the period of sampling. Trap efficiency tests must be conducted regularly to accurately estimate the number of downstream migrating smolts.

Trap efficiency tests are essentially mark-recapture experiments. Each week, 50 – 100 smolts of each species are marked, then released upstream from the trap. The number of marked smolts recaptured is then recorded on subsequent dates. Smolts for marking and releasing should be selected from those captured in the trap the previous night. Frequently not enough smolts are captured during a single night to allow for an accurate trap efficiency estimate. Therefore, efficiency estimates may be calculated on a daily basis using the formula:

$N_i = n_i / (m_i \text{ recapture} / m_i \text{ release})$

Where N_i = total number of migranting smolts passing trapping location in week 1,
n_i = number of unmarked fish caught in trap in week 1,
m_i recapture = number of marked fish recaptured in trap on week 1,
m_i release = number of marked fish released above the trap in week 1,

The total number of fish migrating past the trap site for the season is then estimate by:

$$N_{total} = \sum N_i$$

Improved trap efficiency estimates can be achieved by releasing marked smolts at dusk. This is because most downstream migrating salmon smolts migrate at or soon after dusk and repeatedly releasing marked fish at the same spot every day can lead to increased predation by resident cutthroat trout. Releasing smolts at dusk reduces predation by reducing the time of marked fish are exposed to predators.

Salmon and steelhead smolts that are marked for efficiency estimates must be allowed time to recover from handling prior to release. This can be accomplished by using a timer-activated, self-releasing live box. Traps are checked in the morning and marked smolts are placed in the self-releasing live box to recover before being released at dusk. The self-releasing live box consists of three dark-colored five-gallon buckets that are suspended between two small floating pontoons. A spring wound timer is connected to a 12-volt automobile door lock actuator. At the appropriate time, the timer energizes the door lock actuator, which pulls a pin releasing the buckets. The buckets pivot on a pipe inserted through holes in their base, turn upside down, and release the fish. Each bucket has wire mesh panels along their sides to allow transport of oxygenated water into them. Periodically the fish are examined just prior to release to make sure that there is no mortality and that the buckets dump at the appropriate time.

The release location for marked fish for trap efficiency estimates is located far enough upstream so the fish can evenly mix with unmarked fish moving downstream, yet not be so far upstream as to cause an extracted period of migration of marked fish over multiple days. Marked fish are typically released at least two pool/riffle units, but no more than 300 meters, above the trap.

In some streams, the number of migrating smolts caught in the trap insufficient to obtain a weekly trap efficiency estimate. Low catches may result from a low number of migrants, low trap efficiency, or a combination of both. If weekly trap efficiency estimates are not possible, an efficiency estimate for the entire season is calculated based on the total number of marks released and recaptured while the trap was in operation. This seasonal trap efficiency estimate is used to expand the number of fish caught in the trap during the season to obtain an estimate of total migrants. The use of seasonal trap efficiency in calculating total smolts migrating is usually results in less accurate estimate than estimates expanded from weekly trap efficiency. Loss of accuracy is the result of expanding estimates of smolts migrating from low numbers where a difference of one or two fish can change estimates substantially.

Fish Handling

Any smolts, or other fish, that are handled for marking or size measurements should be anesthetized. Recognized fish anesthetic agents include tricaine methanesulfonate (MS222), Alkaseltzer ™, and clove oil. Human health concerns have been raised over chronic exposure to MS222, therefore any personnel using this agent should be familiar with cautions explained on the material safety data sheet accompanying the product and should take appropriate precautionary measures. Effectiveness of anesthetic agents varies with concentration of the agent, water temperature, and fish density. Those using anesthetics should be familiar with dosage recommendations. Oxygenated, cool water should be provided to smolts being held before anesthesia and those recovering from anesthesia.

Marking smolts for trap efficiency tests may be accomplished in several non-destructive ways. Often the upper or lower tip of the caudal fin is clipped using small scissors or a razor blade. Different colors of acrylic paint can also be injected under the skin using either a Panjet needleless injector or small hypodermic needle.

V. Quality assurance and quality control

Quality assurance and quality control procedures should be established for each salmon and steelhead smolt trapping program. These procedures should include elements of training, data entry and management, and independent assessment of methods.

The training program should address:

1) safety practices,
2) identification of fish species likely to be encountered,
3) proper handling of fish and
4) data entry and management.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper use of measuring boards and balances, data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check 5 – 10% of the original entries.

VI. References

Keeley, E.R., and C.J. Walters. 1994. The British Columbia watershed restoration program: summary of the experimental design, monitoring and restoration techniques workshop. Ministry of the Environment, Lands and Parks and Ministry of Forests, Watershed Restoraton management Report No. 1. 34 pp.

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Todd, G.L. 1994. A lightweight, inclined-plane trap for sampling salmon smolts in rivers. Alaska Fishery Research Bulletin 12:168-175.

Migrant smolt trapping data sheet.

Date:	Page ___ of ___
Time:	Site: (Lat/Long or UTM)
Stream name:	Personnel:
County:	Stream condition:

Fry	**Total number**	**Smolts**	**Total number**
OC		**OC**	
OK		**OK**	
OM		**OM**	
OT		**OT**	
TR		**TR**	

Species	**Length (mm)**	**Weight (g)**	**Mark applied**	**Recapture mark**	**Mortality**	**Comment**

Meta data for migrant smolt trapping.

Item	Description
Date	Calendar date (MM/DD/YY)
Time	Military time (HHMM)
Stream name	Stream name on USGS 1:24,000 Quad. Map
County	California county name
Location	Coordinates of trap site in either latitude and longitude or UTM
Stream condition	Includes discharge or stage height if available, amount of debris visible, turbidity.
Page	Number pages consecutively
Personnel	Name of field personnel recording data
Species code	
OC	Cutthroat trout
OK	Coho salmon
OM	Steelhead
OT	Chinook salmon
TR	Trout too small (< 80 mm) to accurately identify
Total number	Total number of each species collected on that date
Length	Fork length in mm
Weight	Wet weight in g
Mark applied	Type and location of any mark applied to fish
Recapture mark	Type and location of mark on any recaptured fish
Mortality	Record if fish died during collection
Comment	Note any unusual conditions or circumstances.

6. Adult Salmon and Steelhead Escapement

I. Rational

Estimates of the number of adult salmon or steelhead returning to spawn provide essential information on the size of populations. The number of adults escaping to spawn is influenced by mortality at all younger life history stages. Since habitat conditions in freshwater and the ocean influence survival, estimates of escapement are the often considered the ultimate measure of population response.

II. Limitations

Estimating numbers of salmon or steelhead escaping will not be possible in all streams. Present methods rely on visual observation of adults. In streams that remain turbid for periods during the spawning period, visual observations are often not possible. Visual observation techniques also require that observers regularly census portions of streams where spawning may occur, and this requires considerable labor.

III. Sampling Methods

Personnel and training

One or two people are needed to gather data for estimating escapement. For safety reasons, we recommend two people be devoted to collecting these data. Personnel should be trained to identify adult salmon and steelhead, whether alive or dead.

Gear needed

No specialized gear is needed to carry out escapement estimates. A list of basic equipment sufficient to gather these data includes:

1) Chest waders
2) Rain gear
3) Hip chain
4) Flagging
5) Write-in-the-Rain notebook or data sheets.
6) Polarized glasses, amber or brown are preferred.

Survey methods

Sampling should begin when the first adult salmon or steelhead enter the stream of interest and continue until no adults are observed. Most species of salmon complete spawning over a period of two months or less. A hip chain is used to measure distances when conducting the initial observations. During this initial sampling, plastic flagging can also be affixed to riparian vegetation at 50 – 100 m intervals and a distance written on the flagging with a waterproof marker. If this is done, distances at which fish are observed during subsequent sampling dates may be estimated.

Sampling frequency should be guided by the period of residence for individual adult fish. We have estimated the average residence time of adult coho salmon to be eight days in Prairie Creek, Humboldt County, California. Ideally, one would repeat sampling for coho salmon in this stream every eight days. However, entry of adult fish into streams is not regular and through analysis of past we determined that a sampling frequency of 10 days is sufficient to provide escapement estimates.

Sampling during each of these periods involves two personnel walking every stream reach of interest. Observations of both numbers and location (m upstream) of live fish and salmon carcasses are recorded. Record both species and sex of individual adults or carcasses. Recording the number of jacks can provide initial data. A disc type tag having a number is affixed to salmon carcasses with plastic electrical ties when they are first observed. The condition of salmon carcasses (Sykes and Botsford 1986) is recorded each time they are observed (see Appendix Table) as are numbers from carcasses previously tagged.

Efficiency
The ability of each observer to see fish should be measured to provide an estimate of efficiency. This may be accomplished by having the crew separate during short portions of a survey, each record data separately, and submit their results "blind." The alternative is to have a second trained crew visit sites sampled earlier. Time elapsed between the survey and efficiency check should not exceed three or four hours since adult fish may move.

Data analysis
Analysis of escapement data involves developing an estimate of total population size using data from observations made at intervals during the period of spawning. Either carcasses or live fish may be used to estimate escapement. Estimating escapement from periodic counts of live fish has been accomplished using area-under-the-curve techniques (English et al. 1992). These methods are best suited to streams having a weir or other obstruction at which fish entering the stream may be counted. However, they can be employed on streams lacking a weir.

Capture-recapture methods are usually employed to estimate escapement from carcass data. These methods range from simple Lincoln type index to more rigorous statistical methods (Sykes and Botsford 1986, Schwarz et al. 1993). However, when working with low numbers of fish, assumptions of some of the more rigorous methods often cannot be met. We present the steps for calculating an estimate of escapement using the Lincoln type index in Box 6.1 and refer readers to the specialized literature on more rigorous methods.

Box 6.1. Calculating salmon escapement from carcass data using a simple Lincoln index.

1. *During sampling period 1 record*:

1) 1) n_1 - the total number of carcasses observed and
1) 2) a_1 - the total number of carcasses marked.

2. *During sampling period 2 record*:

1) 1) n_2 - the total number of carcasses observed,
1) 2) r_2 - the total number of marked carcasses observed and
1) 3) a_2 - the total number of new carcasses marked.

3. Calculate the estimated number of adults (N) in the area during the period as:

$$N = a_1^2 * (n_2 + 1) / (r_2 + 1)$$

4. The variance of this estimate is calculated as:

$$V = a_1^2 * (n_2 + 1)*(n_2 - r_2) / (r_2 + 1)^2 * (r_2 + 2)$$

5. *During sampling period 3 record the same data recorded during period 2 and calculate N for the interval 2-3, continue this process until the period of sampling is covered.*

IV. Considerations Before Sampling

Natural Variability

Numbers of adult salmon returning to spawn varies among years. In streams with low total population size, variation in escapement may limit the ability of this measure to detect a signal from watershed restoration.

> **We used power analysis to evaluate the ability of escapement estimates to detect a 10% increase in population size over years (Gibbs 2003). The data used were for coho salmon from Prairie Creek, Humboldt County, California, during 1999-2002. Escapement estimates ranged from 49 – 353 adults during this period.**

Conditions we assumed were that one estimate would be available for monitoring each year and that the coefficient of variation among years was 50%. We set α at 0.10, and ran 500 iterations of a 2-tailed t-test to estimate how many years of sampling would be required to detect change at a desired power level of 0.80. Results from this analysis suggest that, in Prairie Creek, it would require 15 years to detect a 10% increase in population size (Figure 6.1).

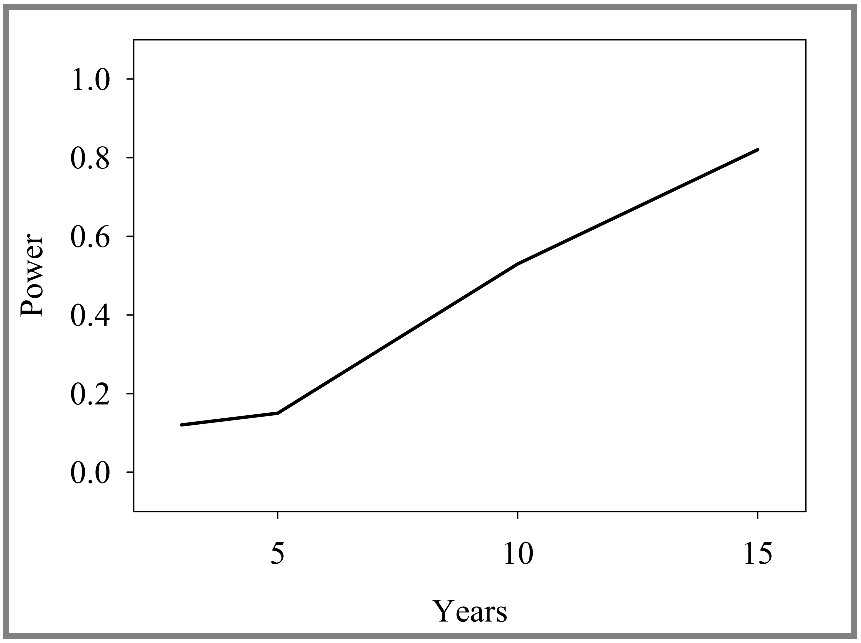

Figure 6.1. Power to detect a 10% increase in adult coho salmon escapement to Prairie Creek, California.

V. Quality assurance and quality control

Quality assurance and quality control procedures should be established for all programs estimating salmon and steelhead escapement. These procedures should include:

Training that addresses,

1) safety practices in the field and hypothermia,
2) identification of adult salmonid species likely to be encountered,

The quality assurance plan for data entry and management should include,

1) data entry
2) data management
3) data analysis
4) chain of custody for data

The assurance for fish sampling should include independent assessment of efficiency as discussed above.

Data entry and management elements of QA/QC procedures should include the use of metric units of measure, proper data coding of field sheets and data entry. Procedures to verify the accuracy of recorded field data and data entry into an electronic format should be developed. These typically involve an independent observer check of 5 – 10% of the original entries.

VI. Literature Cited

English, K.K., R.C. Bocking and J.R. Irvine. 1992. A robust procedure or estimating salmon escapement based on the area-under-the-curve method. Canadian Journal of Fisheries and Aquatic Sciences 49:1982-1989.

Gibbs, J.P. 2003. Monitor: online software for estimating the power of population monitoring programs to detect trends in plant and animal abundance. http://www.mbr-pwrc.usgs.gov/software/monitor.html.

Schwarz, C.J., R.E. Bailey, J.R. Irvine and F.C. Dalziel. 1993. Estimating salmoon spawning escapement using capture-recapture methods. Canadian Journal of Fisheries and Aquatic Sciences 50:1181-1197.

Sykes SD, and LW Botsford. 1986. Chinook salmon, Oncorhynchus tshawytscha, spawning escapement based on multiple mark-recapture of carcasses. Fishery Bulletin: Vol. 84, No. 2: 261-270.

Salmon and Steelhead escapement data sheet.

Date:	Page ___ of ___
Time:	Site boundaries: (Lat/Long or UTM)
Stream name:	Personnel:
County:	Stream condition:

Distance	**Species**	**# Live**	**# Carcass**	**Carcass condition**	**Mark number**	**Recapture number**

Meta data for salmon and steelhead escapement data sheet.

Item	**Description**
Date	Calendar date (MM/DD/YY)
Time	Military time (HHMM)
Stream name	Stream name on USGS 1:24,000 Quad. Map
County	California county name
Location	Coordinates of trap site in either latitude and longitude or UTM
Stream condition	Includes discharge or stage height if available, amount of debris visible, turbidity.
Page	Number pages consecutively
Personnel	Name of field personnel recording data
Distance	Distance in meters upstream from starting point.
Species code	
OK	Coho salmon
OM	Steelhead
OT	Chinook salmon
# Live	Total number of that species observed at that distance location.
# Carcass	Total number of that species carcasses observed at that distance location.
Carcass condition	
1	Recently died, eyes clear and flesh firm
2	Eyes are cloudy, but flesh still firm
3	Eyes are cloudy and flesh is soft
4	Eyes are cloudy and flesh is very soft, beginning to slough off
5	Only the head and part of the skeleton remain
Mark number	Number of mark applied to that carcass.
Recapture number	Number of mark existing on that re-sighted carcass.

APPENDIX A:

Table 1. Watershed restoration action categories, objectives of these actions and validation monitoring criteria.

Restoration Action	Validation Monitoring Criteria
Fish Passage Objective: To improve fish passage and access.	Presence of adult or juvenile life stages of salmon or steelhead.
Fish Sceens Objective: To prevent fish from accessing waterbody.	Absence of juvenile salmon or steelhead.
Instream Habitat Restoration Objective: Increase cover, habitat or complexity or increase interaction of stream and floodplain.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Streambank Stabilization Objective: Increase bank stability and reduce erosion.	Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Riparian Land Use Control Objective: Eliminate livestock use of stream to increase bank stability, reduce erosion and promote riparian vegation.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Control vegetation Objective: Increase native vegetation, reduce exotic vegetation and increase fish habitat.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Riparian Vegetation Management Objective: Increase shade, bank stability, LWD recruitment and nutrients.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Restore Water Flow Objective: Improve stream flow to benefit fish and riparian plants.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.

Restoration Action	Validation Monitoring Criteria
Slope Stability or Erosion Control Objective: Reduce erosion and sediment delivery to stream.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Gully Repair Objective: Reduce erosion and sediment delivery to stream.	Presence of adult or juvenile of salmon or steelhead. Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead.
Road Upgrading or Decommissioning Objective: Reduce erosion and sediment delivery to streams.	Relative abundance of juvenile of salmon or steelhead. Condition of juvenile salmon or steelhead. Salmon and steelhead spawner/recruit ratio.
Combined Restoration Actions Objective: To improve fish populations within a sub-watershed or watershed.	Size of juvenile of salmon or steelhead population. Condition of juvenile salmon or steelhead. Age structure of juvenile steelhead. Salmon or steelhead escapement. Salmon and steelhead spawner/recruit ratio. Salmon and steelhead smolt production.